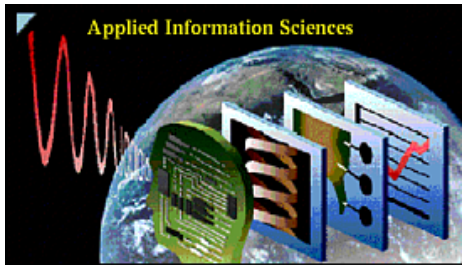

Knowledge Discovery and Data Mining Based on Hierarchical Segmentation of Image Data

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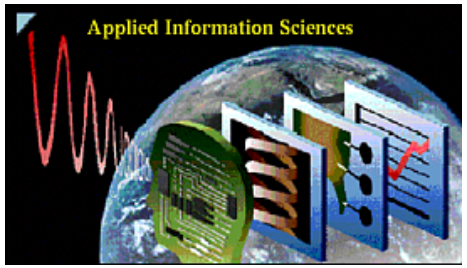

Project Members

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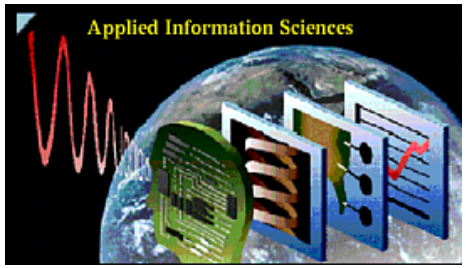


Project Objectives

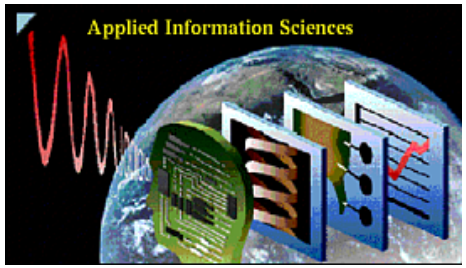
Develop Knowledge Discovery and Data Mining tools which:

i. Utilize a Hierarchical Segmentation representation of image data combined with

ii. Knowledge Discovery and Data Mining tools developed by

   a. Insightful Corporation: VisiMine, originally developed under a NASA SBIR contract, and

   b. German Aerospace Agency – DLR: Incorporate insights from an Image Information System developed by DLR.



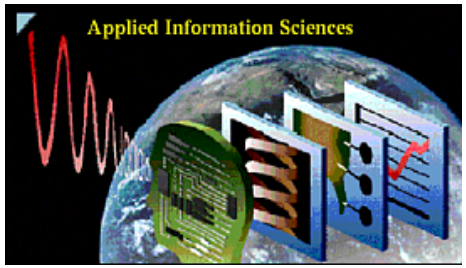
What is a Hierarchical Image Segmentation?

A set of image segmentations that

i. consists of segmentations at different levels of detail in which

ii. the coarser segmentations can be produced from simple merges of regions from the finer segmentations, and

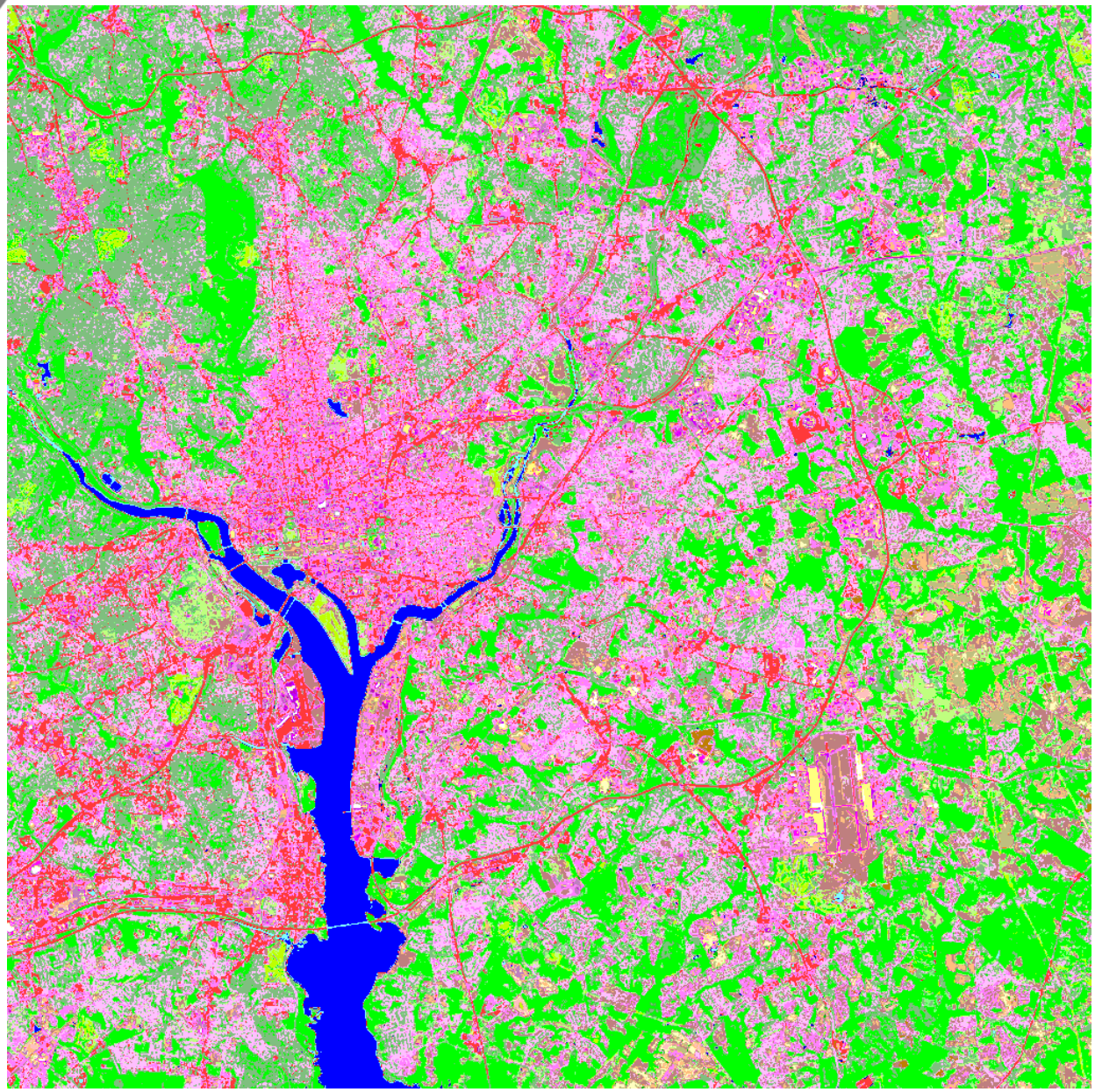
iii. the region boundaries are maintained throughout at the full image spatial resolution.

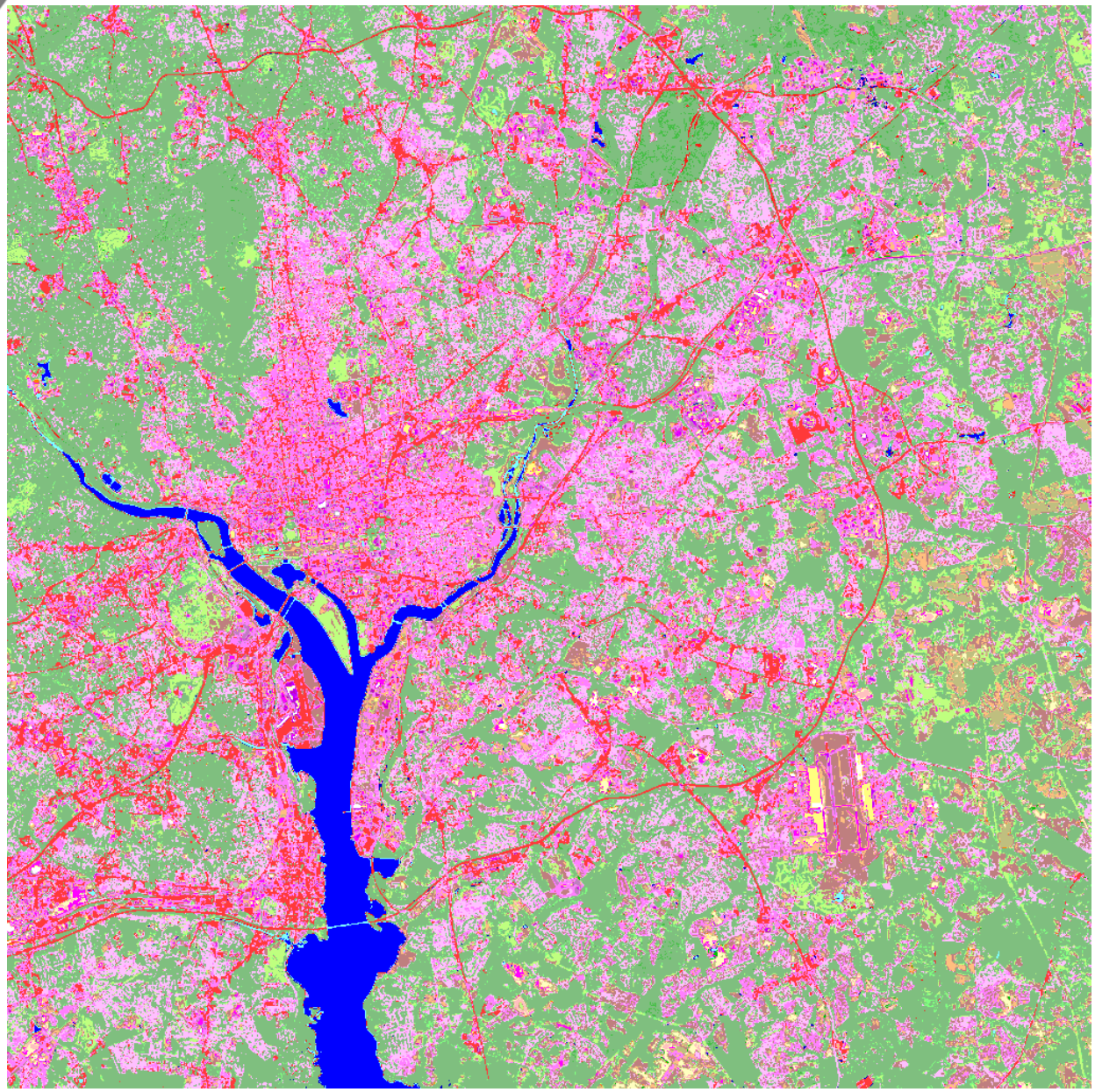


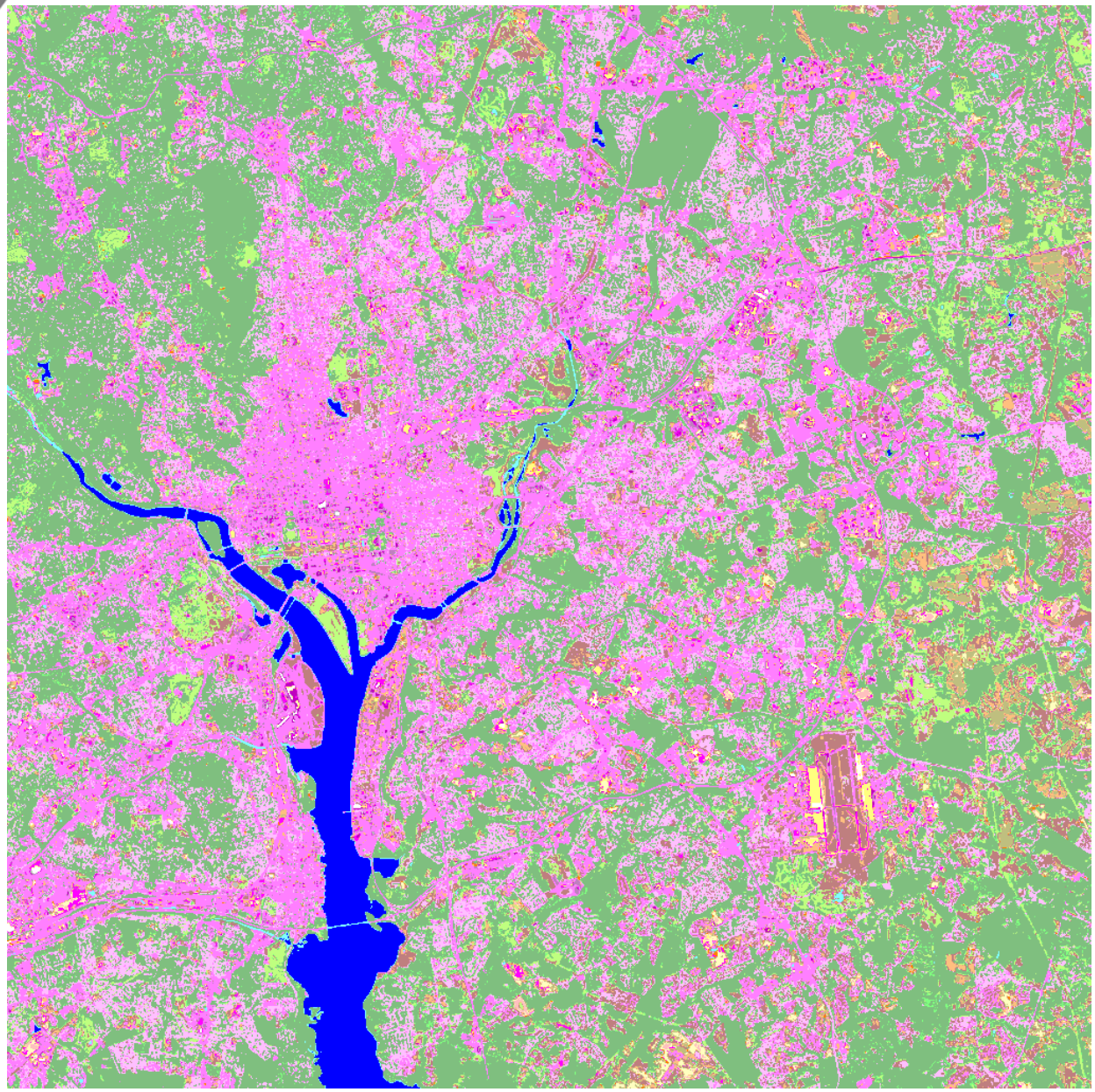
Example: Landsat Thematic Mapper data

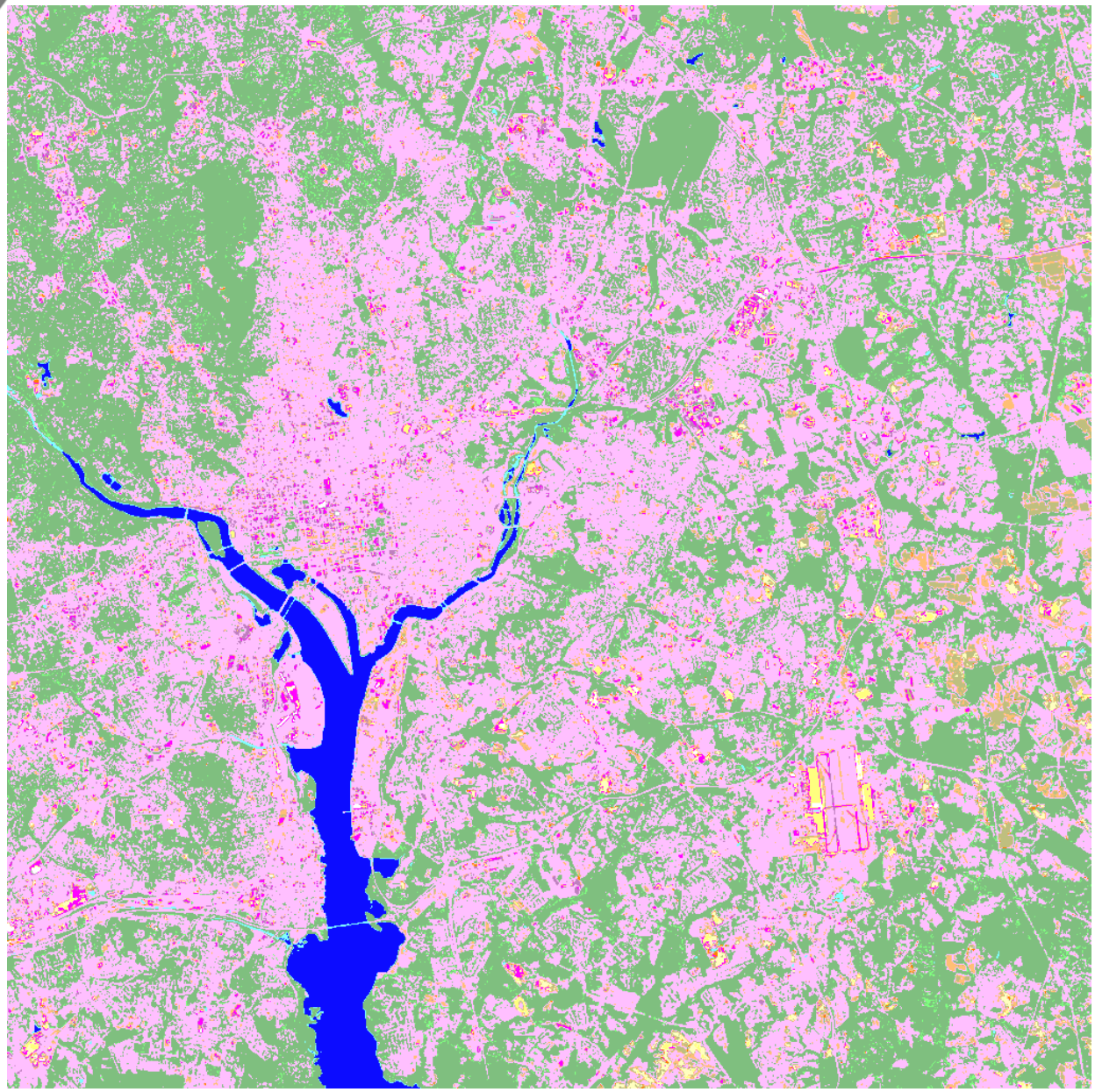
A 1024x1024 pixel section of Landsat ETM+ data obtained on May 28, 1999 over Washington, DC, U.S.A.

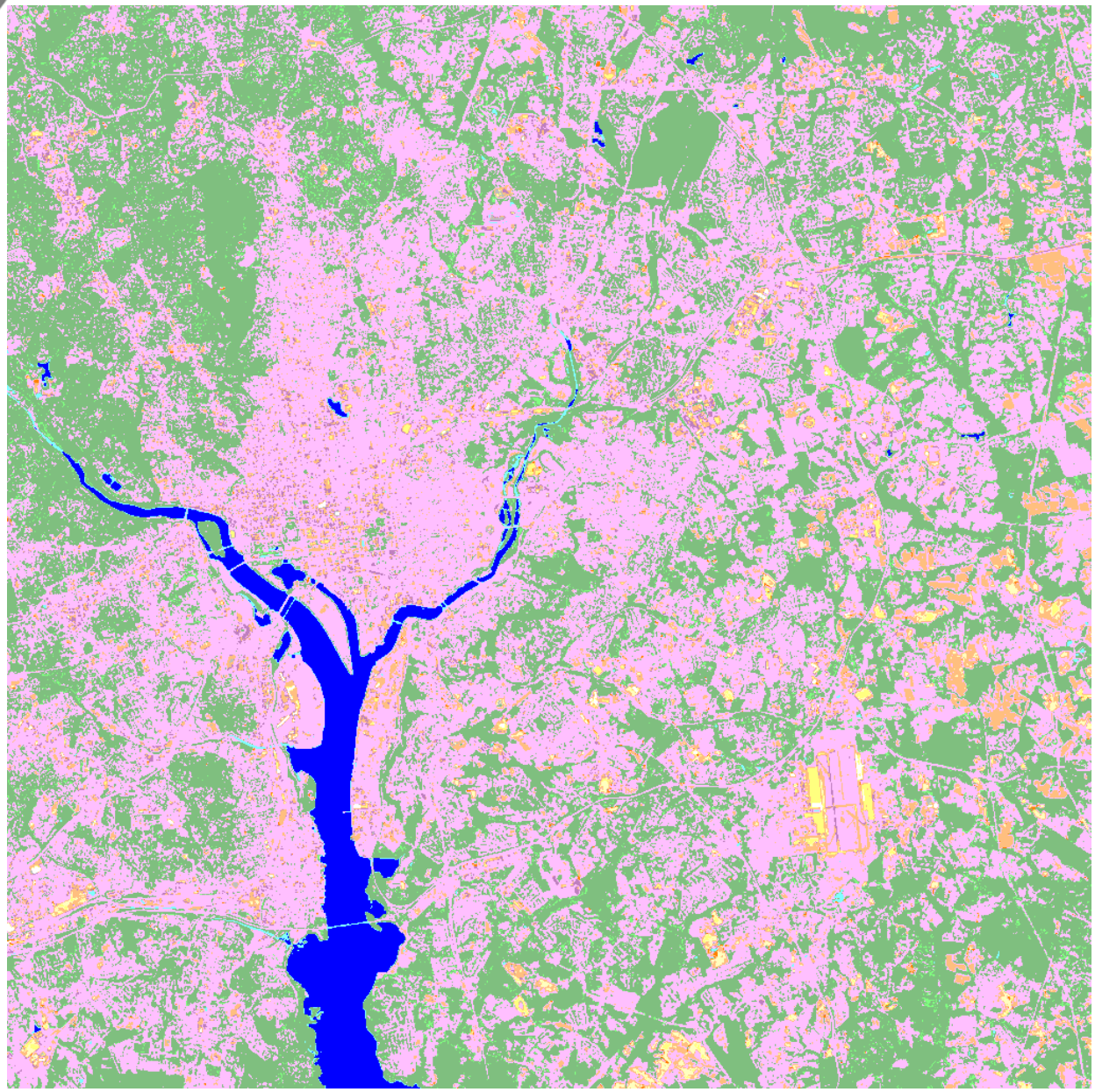
Produced 12 hierarchical segmentation levels (9 shown).

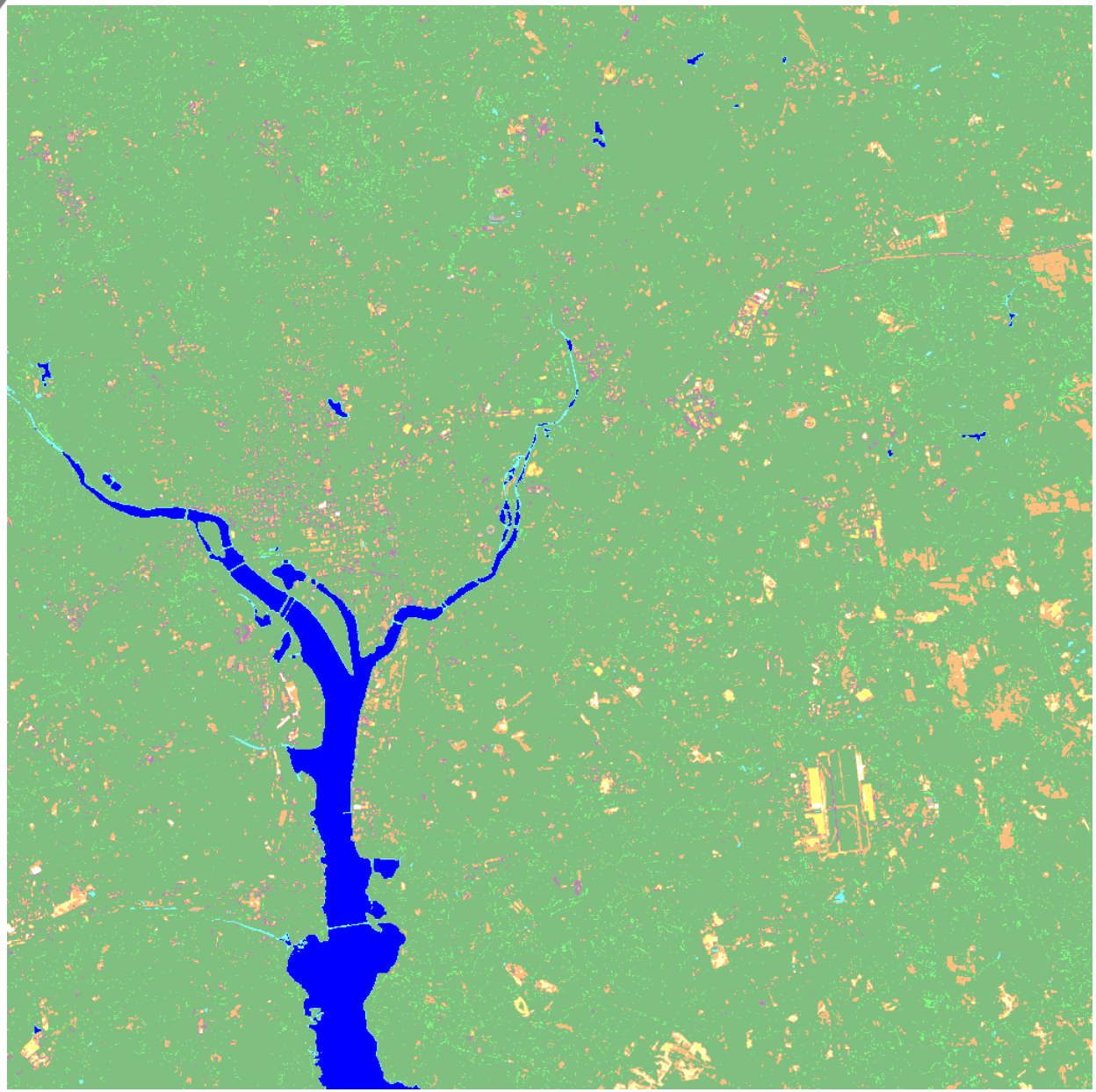


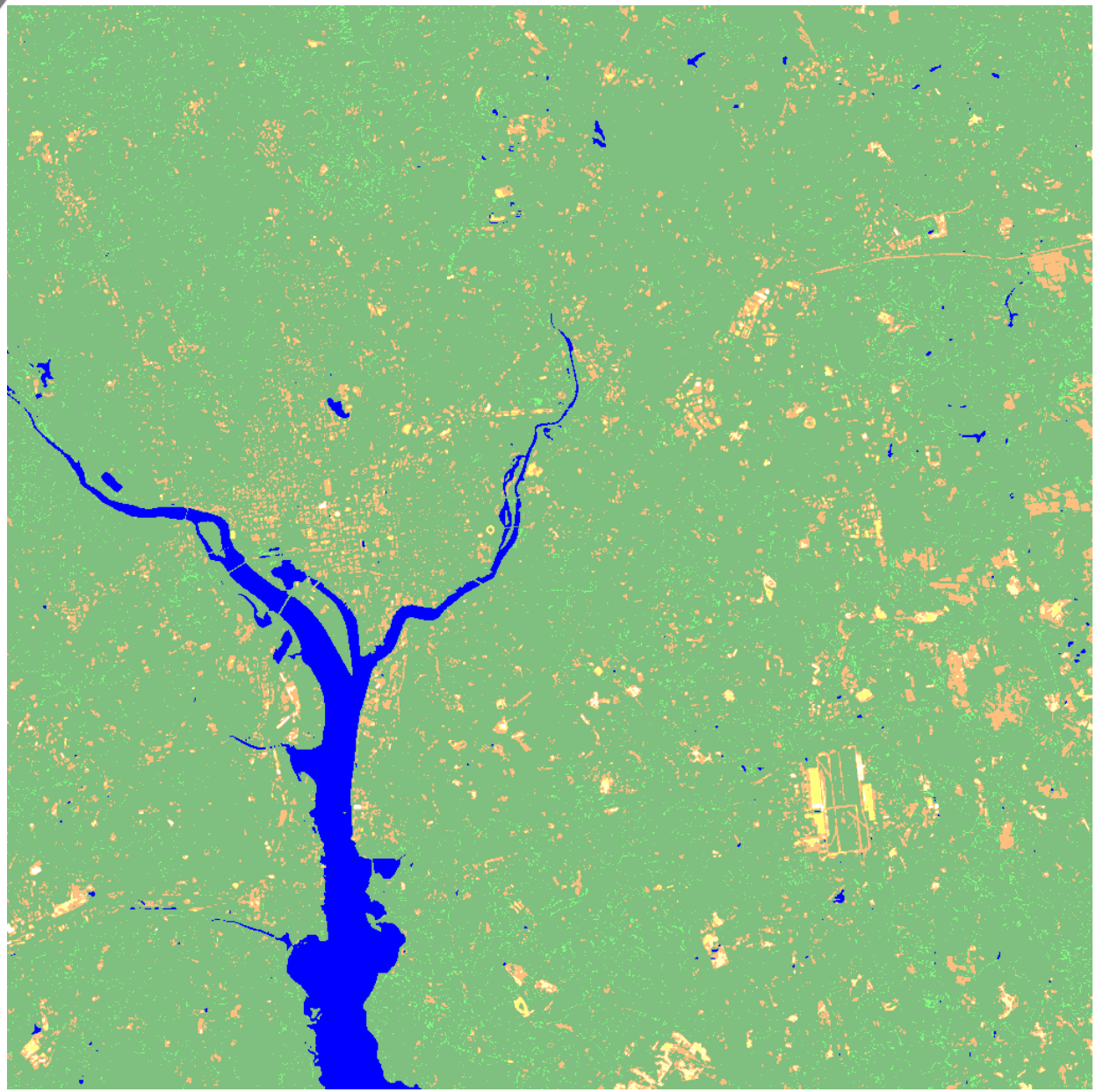


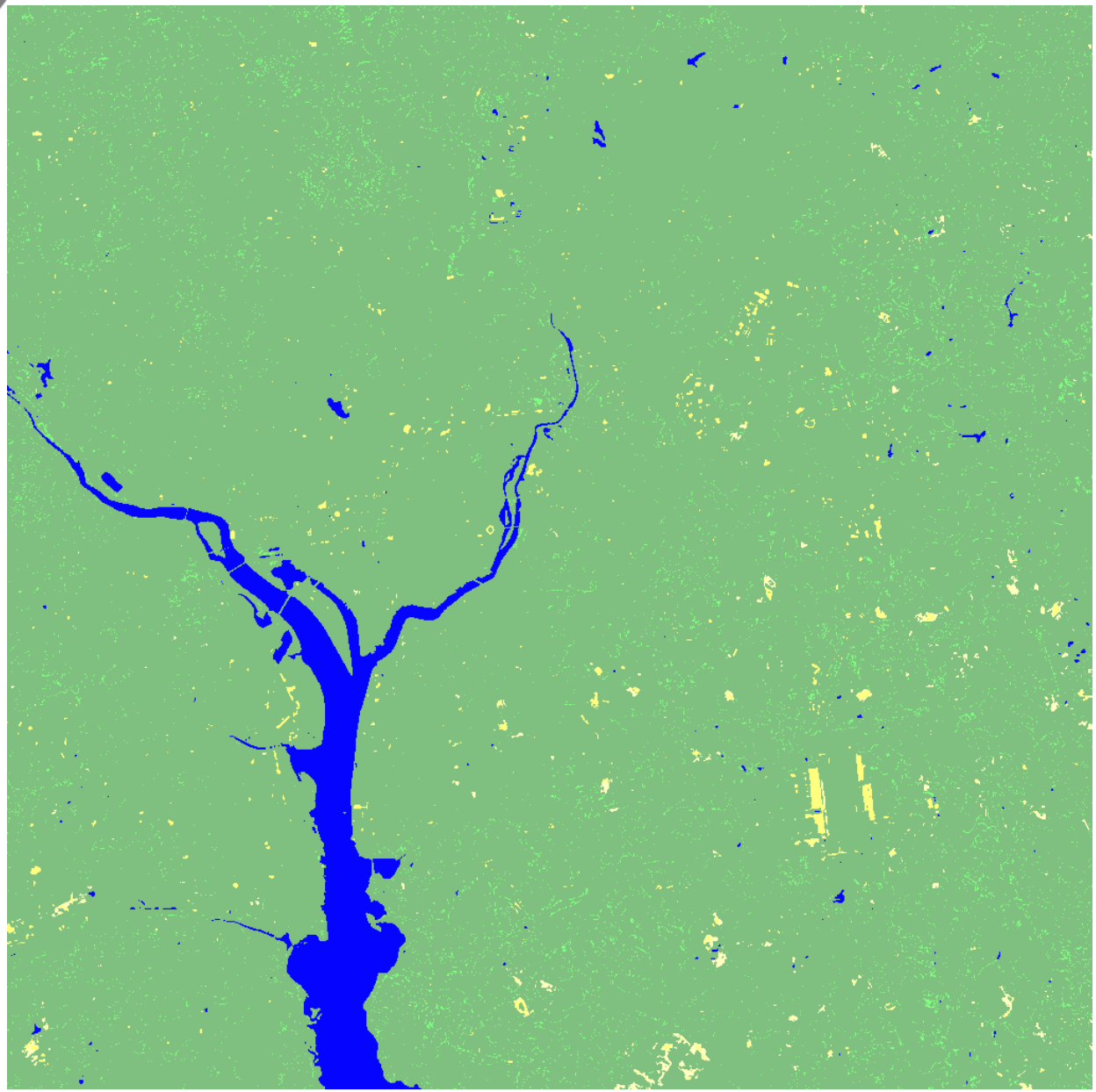


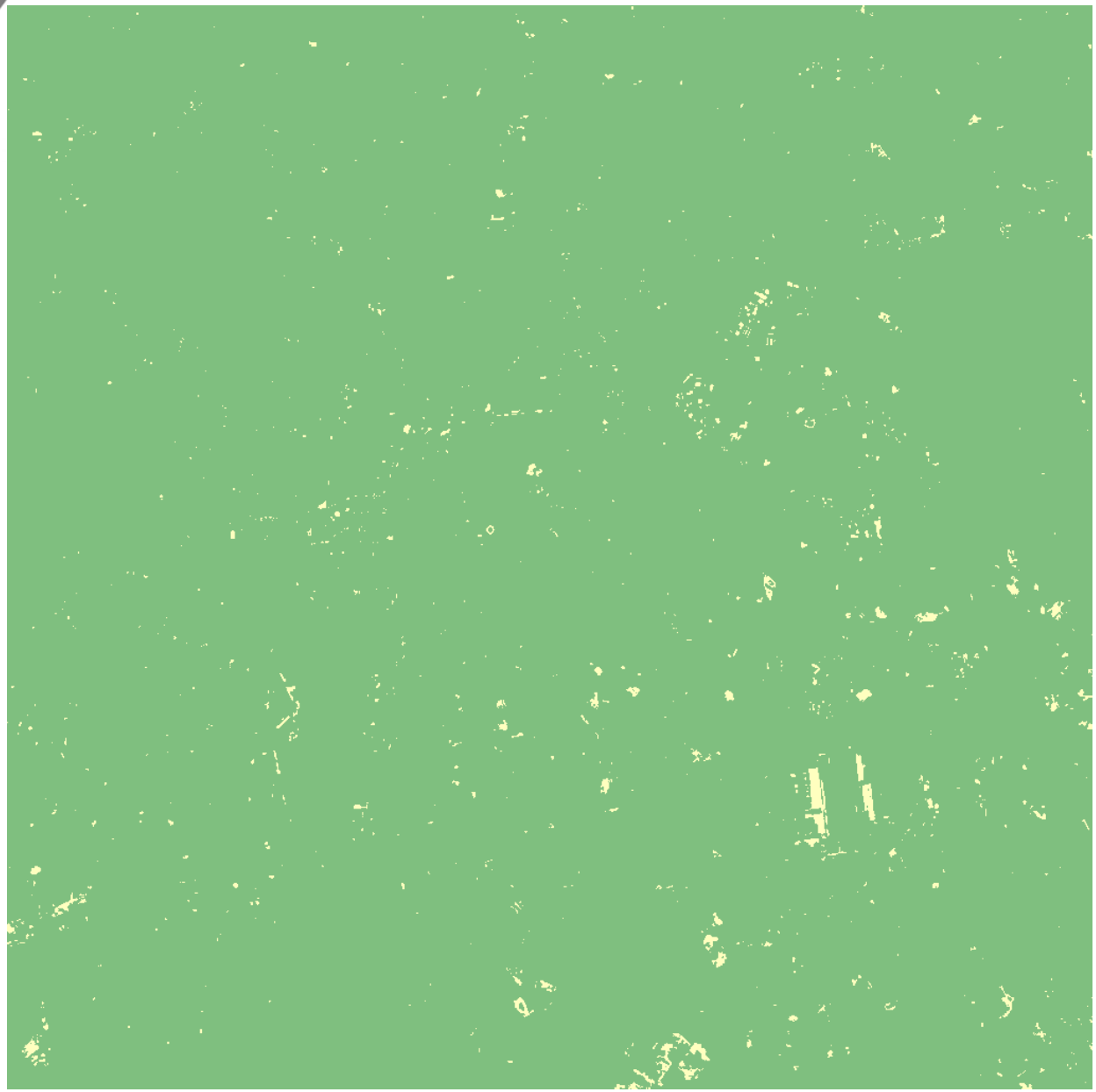


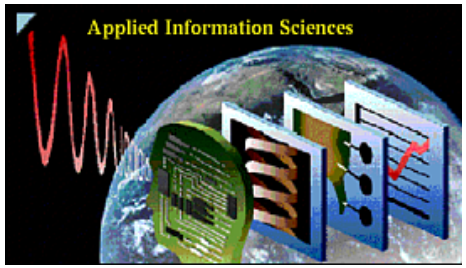










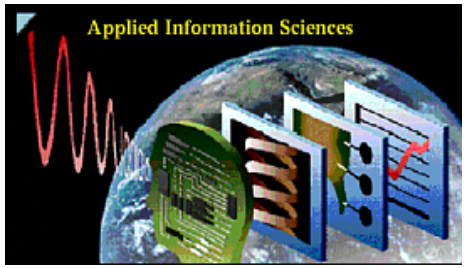


Recursive Hierarchical Segmentation (RHSEG)

RHSEG recursively divides an image into quarter sections until the image sections are small enough where the combinatorial explosion of inter-region comparisons is sufficiently reduced (about 1000 to 4000 pixels).

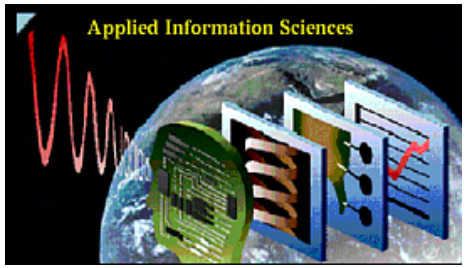
HSEG is performed on each section until a preset number of regions is reached – and the recursion is returned up until the image is fully reassembled (see NASA Case Number GSC 14,328-1).

A fast parallel implementation of RHSEG has been devised and is described in NASA Case Number GSC 14,305-1 (and U. S. patent application no. 5,965,879).



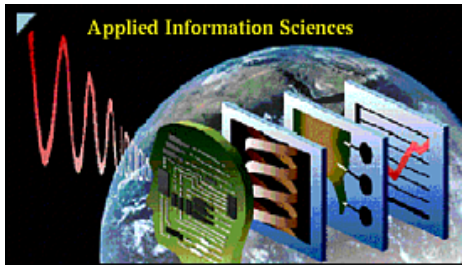
Original Technical Tasks

1. Detailed analysis of region properties embodied in the hierarchical image segmentation,
2. Conversion of the semi-automatic to an automatic approach,
3. Integration of automatic generic region labeling with knowledge discovery and data mining,
4. Integration of RHSEG hierarchical segmentation with GeoBrowse (now called VisiMine),
5. Development of a Visual Grammar,
6. Algorithms for Hierarchical Classification.



Problems Encountered

- Processing window artifacts were observed in large scale results from RHSEG – despite code designed to mitigate the problem.
- A major rewrite of RHSEG was required to solve the problem, diverting time and resources from other planned tasks.
- The first rewrite of RHSEG (completed the fall of 2003) successfully eliminated the processing window artifacts but used too much RAM memory to efficiently process large images.
- A second rewrite of RHSEG (completed the fall of 2003), not only successfully eliminated the processing window artifacts but also substantially reduced RAM memory requirements.

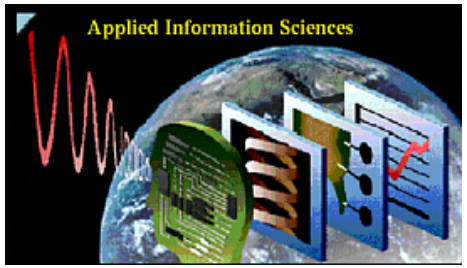


RHSEG Development Accomplished under IS Project

- Developed an approach for eliminating processing window artifacts. This major breakthrough is described in "A Method for Recursive Hierarchical Segmentation which Eliminates Processing Window Artifacts," NASA Case Number GSC 14,681-1 (patent application in process).

  With this approach to artifact elimination, RHSEG can now reliably produce artifact free results for large images in acceptable processing times.

- Improved utilization of RAM memory in parallel implementation of RHSEG. Now can process a very large image (e.g., a 6900x6500 6-spectral band Landsat TM image) in less than 10 minutes on an economical 256 CPU Beowulf PC Cluster.



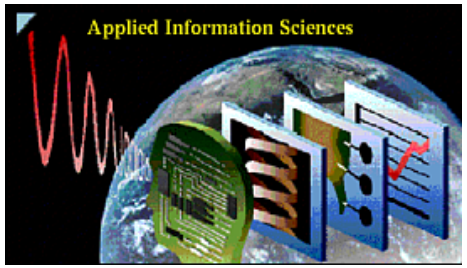
RHSEG Development Accomplished under IS Project (cont'd)

- The HSEG/RHSEG program was augmented to produce additional outputs that will help identify regions of interest and better interface with VisiMine. These additional outputs include:

  (i) The number of boundary pixels in a region (the total number of pixels was an output in the original version), and

  (ii) when non-spatially adjacent merges are allowed:

  (a) the number of closed connected regions contained in each region.
  (b) the region label map and region features for each closed connected region.



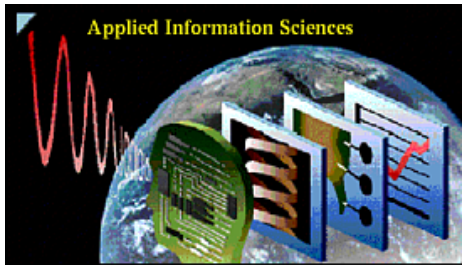
RHSEG Development Accomplished under IS Project (cont'd)

- Implemented a JAVA version of a previously developed "Region Labeling Tool" for exploration of the Hierarchical Segmentation results and give insights on how to exploit the segmentation hierarchy for data mining and knowledge discovery.

This software package, now renamed "HSegViewer":

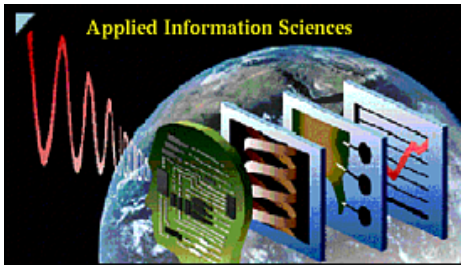
i. allows the selective labeling of regions from different hierarchical segmentation levels, and

ii. provides a quick look at region labels and connected component labeling at each hierarchical segmentation level.



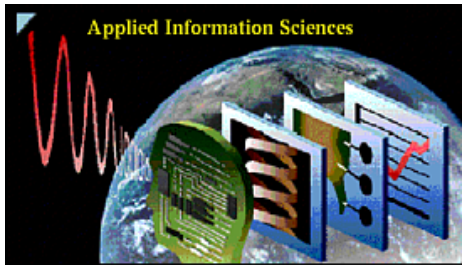
VisiMine

- Originally developed by Insightful Corp. (previously MathSoft) under NASA SBIR Contract NAS5-98053.
- Consists of three main modules:
  - Image processing library.
  - Machine learning and image mining library.
  - Database management system.
- Supported formats: ERDAS (.img), GeoTIFF, BMP, TIFF, BSQ, PNG
- Image indexing levels:
  - Pixel level: Spectral bands, SMA, Gabor and co-occurrence texture, elevation, slope, aspect, custom user defined.
  - Region level: Statistical summaries of pixels, shape.
  - Scene level: Statistical summaries of pixels and regions, spatial relationships of regions.



VisiMine

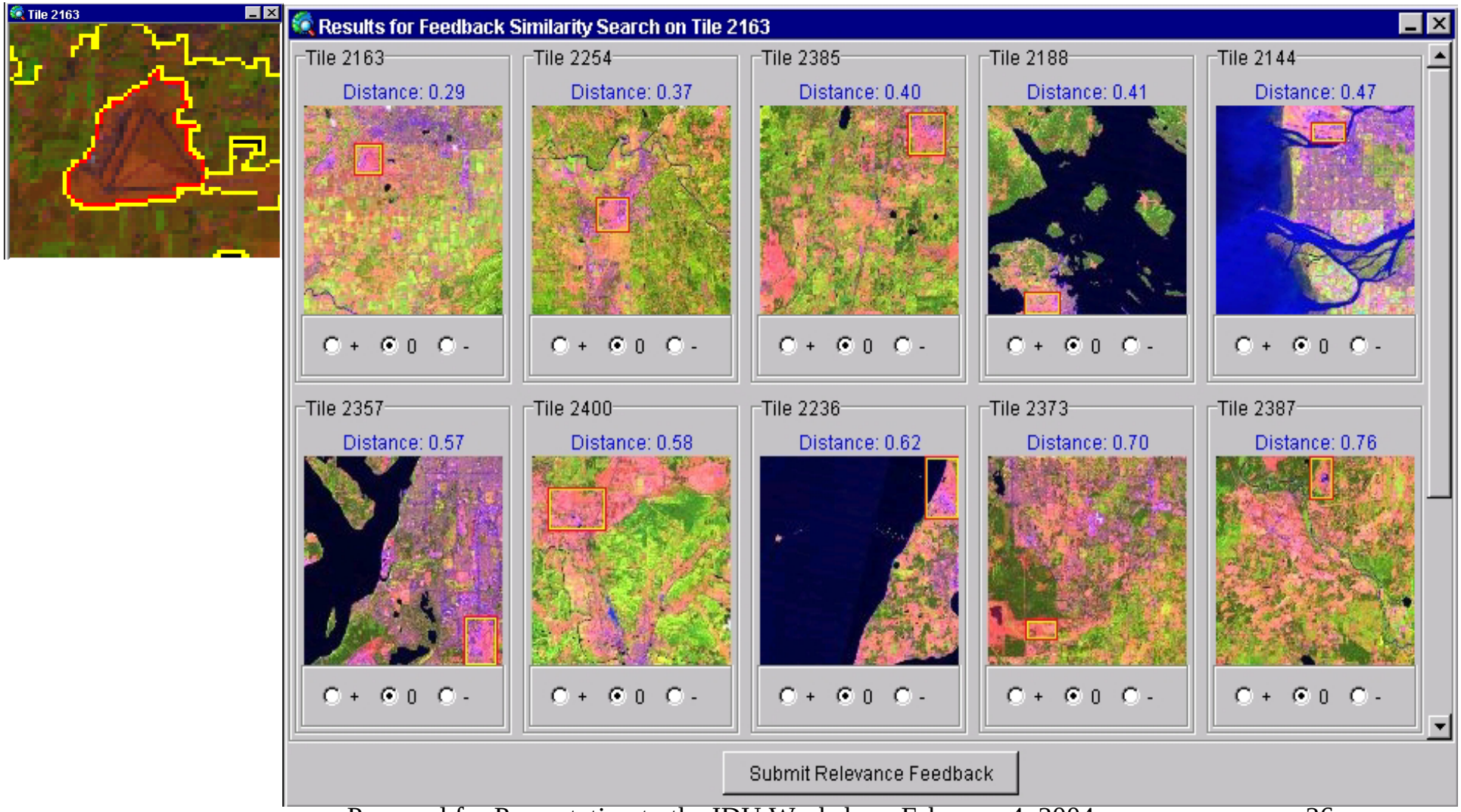
- Knowledge discovery levels:
  - Tile similarity search.
  - Region similarity search.
  - Relevance feedback.
  - Label training and classification.
  - Spatial relationship similarity search.
  - Clustering.
- S-Plus connectivity:
  - Interface to over 4,000 statistical data analysis functions and powerful graphics.
  - Extendable with functions written in S, C, Java and Fortran.

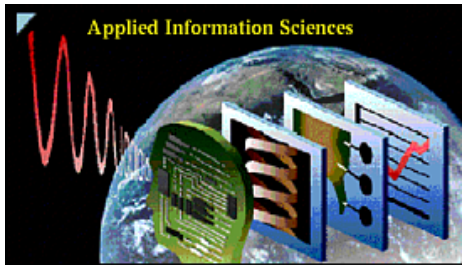


Integration of HSEG into VisiMine

- HSEG imported as pixel feature.
- Tile and region HSEG summaries extracted on any level.
- HSEG improves precision of region retrieval.
- Relevance Feedback and Automated Feature Selection point to relevant levels and segments.
- Used in combination with other feature for land cover classification.

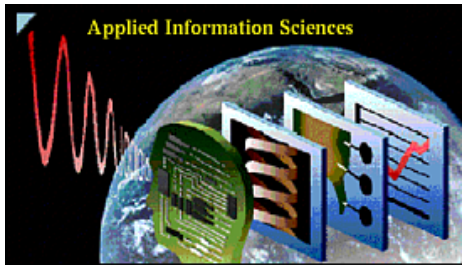
Relevance Feedback Search (after 3rd iteration)



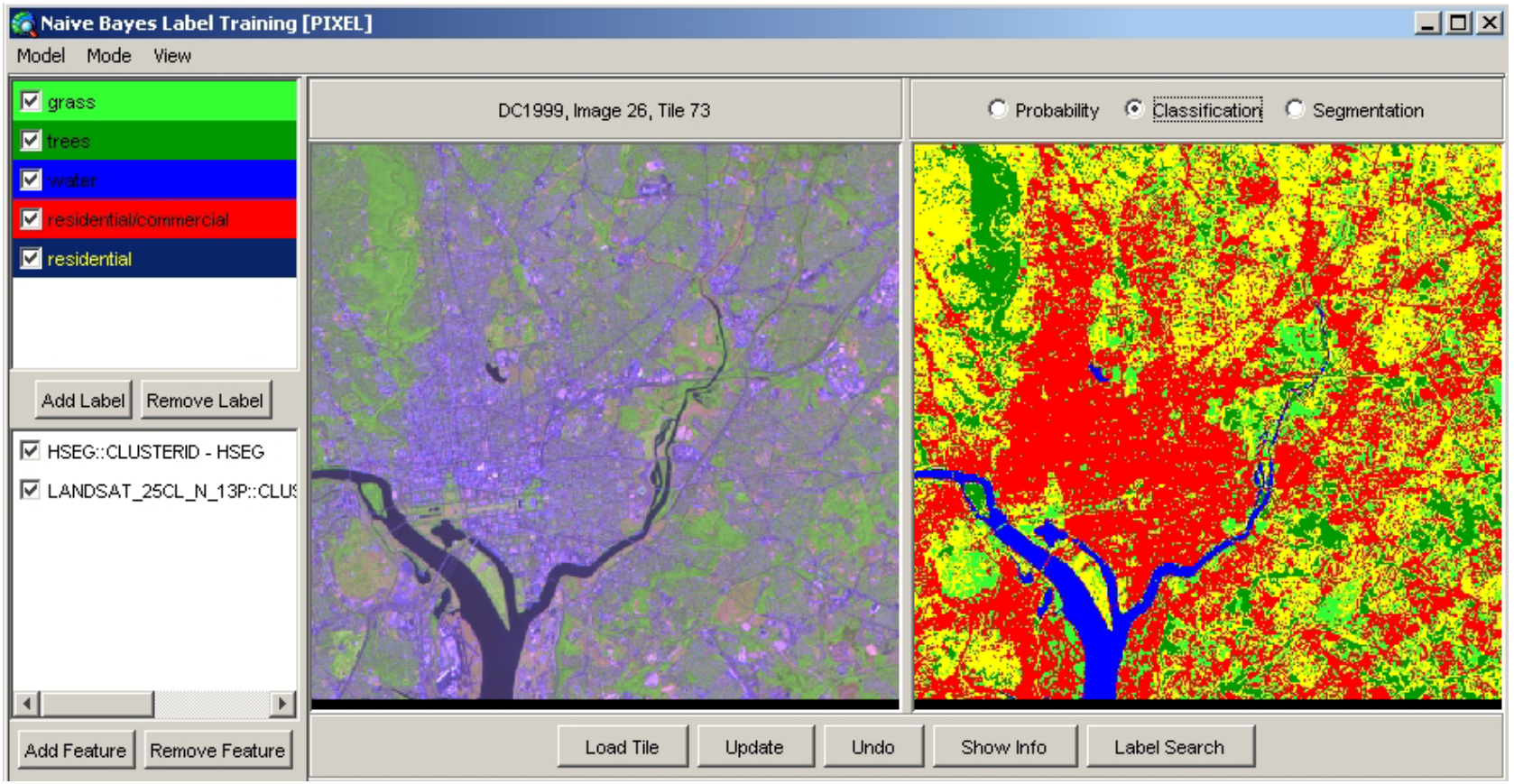


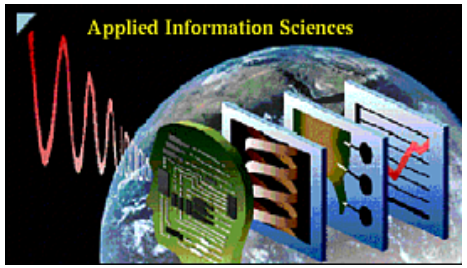
Label training and classification

- Interactive supervised land cover classification
  - Naïve Bayes classifier
  - Decision Tree (under Army contract)
  - Rule classifier (under Army contract)
  - Minimum Distance classifier (under Army contract)
- Missing data handling (under Army contract)
- Pixel and region classification
- Extension to spatial relationship classifier



Label training and classification - example



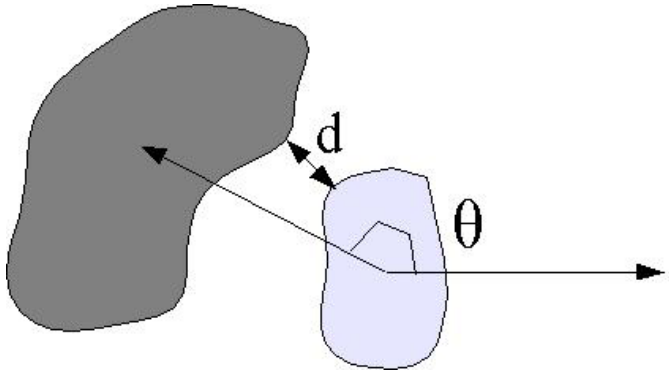


Region Spatial Relationships

VisiMine was enhanced by including a new Visual Grammar approach for interactive classification and retrieval.

Visual Grammar consists to two steps:

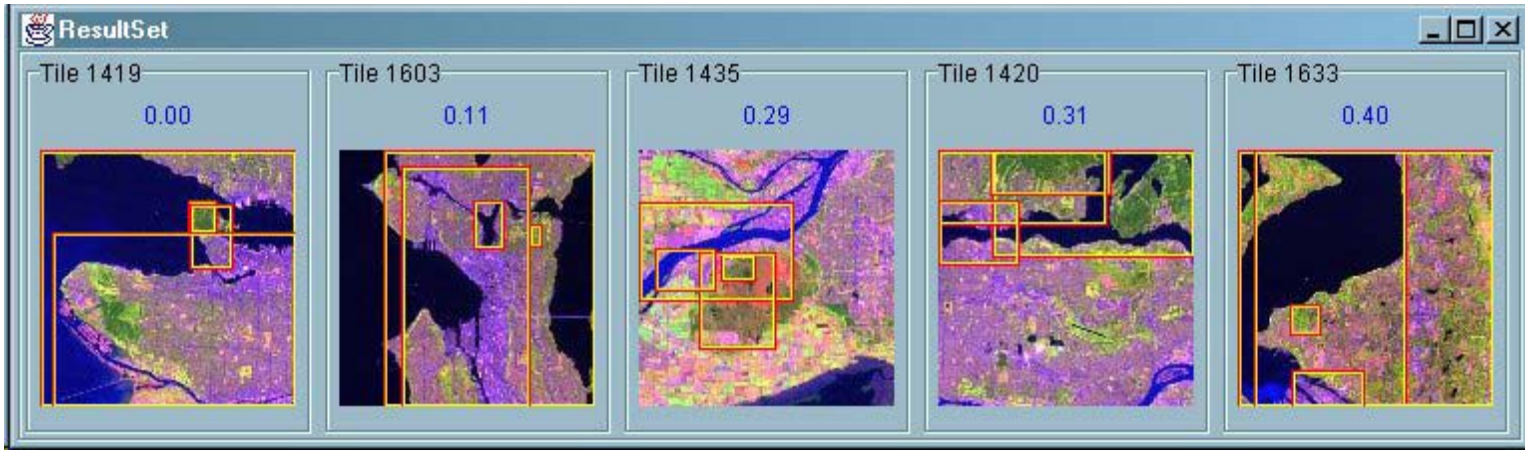
1) Find meaningful and representative regions, called prototype regions.
2) Model each prototype region's spatial relationships using fuzzy modeling of pairwise spatial relationships.



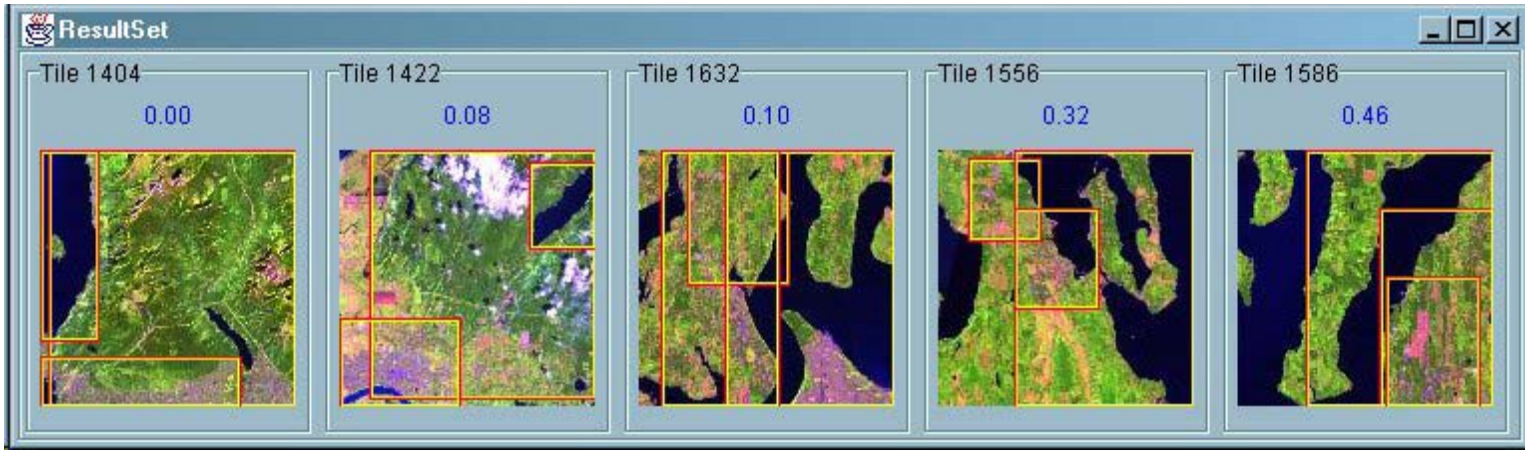
Visual Grammar enables the creation of high-level classes that cannot be modeled using individual pixels or regions.

We will expand Visual Grammar for land use classification.

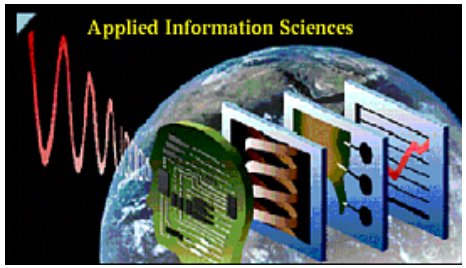
Visual Grammar examples



Searching for scenes where a residential area is bordering a city and both are bordering water, and a park is surrounded by a residential area and is also near water



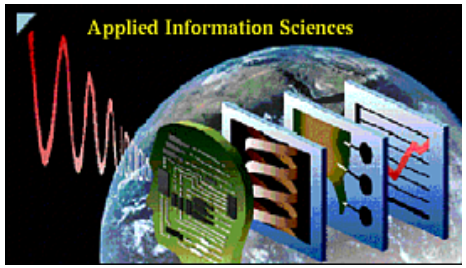
Searching for scenes where a forest is bordering water and is also to the north of a residential area



Future Plans

If proposal to NRA2-38169 is funded:

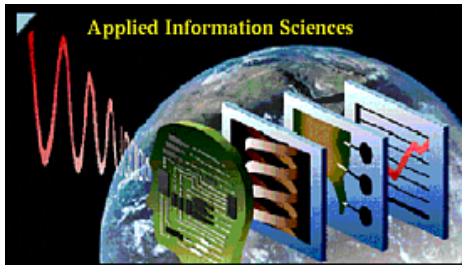
- Fully integrate RHSEG image segmentation with VisiMine.
- Demonstrate and validate this integrated package on data from the MODIS and ASTER instruments for various knowledge discovery and image information-mining scenarios.
- Incorporate additional enhancements and improvements in RHSEG and VisiMine.



Recent Disclosures of Technology

1. James C. Tilton, "A Method for recursive hierarchical segmentation which eliminates processing window artifacts," *Disclosure of Invention and New Technology: NASA Case No. GSC 14,681-1 (revised)*, January 24, 2003.

2. Giovanni B. Marchisio, Krzysztof Koperski, Selim Aksoy and Carsten Tusk, "Knowledge Discovery and Data Mining Based on Hierarchical Segmentation of Image Data and on Visual Grammar," *Disclosure of Invention and New Technology: NASA Case No. GSC 14,696-1*, December 20, 2002.



Recent Publications

1. James C. Tilton, "Analysis of Hierarchically Related Image Segmentations," *Proc. of the Workshop on Advances in Techniques for Analysis of Remotely Sensed Data*, Greenbelt, MD, USA, October 27-28, 2003.
2. Selim Aksoy, Carsten Tusk, Krzysztof Koperski and Giovanni Marchisio, "Scene Modeling and Image Mining with a Visual Grammar," In C. H. Chen, ed. *Frontiers of Remote Sensing Information Processing*, World Scientific, 2003.
3. Carsten Tusk, Krzysztof Koperski, Selim Aksoy, and Giovanni Marchisio, "Automated Feature Selection through Relevance Feedback," *Proc. of the 2003 International Geoscience and Remote Sensing Symposium*, Toulouse, France, 2003.